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Decision Tree for Lead-Based Paint Management on Buildings

Timothy D. Race and Ashok Kumar

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Construction Engineering Research Laboratory
PO Box 9005
Champaign, IL 61826-9005

Final Report

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ABSTRACT: A lead hazard control decision tree was developed for buildings. The tree yields multiple outputs or decisions on 29 branches using only eight queries. This decision tree addresses both lead hazard control for child occupied buildings including family housing, childcare facilities, and schools and non-child occupied buildings such as offices, equipment, utility, storage, shop, and other non-child occupied buildings.

The decision tree employs eight queries to determine a solution for a given set of circumstances. However, each question and answer is laden with significant meaning and requires the user have knowledge from the preliminary investigation of the substrate and paint condition. The criteria presented in query format are based on strategy selection criteria combining regulatory/policy driven strategy selection criteria include: historic preservation, building occupancy, and Army policy. Technology driven selection criteria are substrate condition, paint condition, exposure, and substrate material.

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Conversion Factors

U.S. standard units of measure can be converted to SI* units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

* SI: *Système International d'Unités* (International System of Measurement).

Preface

This technology demonstration was conducted for Headquarters, Department of the Army under Program Element (PE) 063728A, "Environmental Technology Demonstration Project 002, "Environmental Compliance Technology"; Work Unit CF-M B101, "Cost Effective Technologies to Reduce, Characterize, Dispose, and Reuse Sources of Lead Hazards." Bryan Nix, ACS (IM)-FDF, was the Technical Monitor.

The work was performed by the Materials and Structure Branch (CF-M) of the Facilities Division (CF) Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Dr. Ashok Kumar. Part of this work was done by Corrosion Control Consultant and Laboratories (CCC&L), under Contract DACA42-03-P-0086. The Technical Editor was Gordon L. Cohen, Information Technology Laboratory- Champaign. Martin J. Savoie is Chief, CEERD-CF-M and L. Michael Golish is Chief, CF. The Technical Director of the Installation Operations business area is Gary W. Schanche (CV-ZT), and the Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

Many technology options are available for the management of lead-based paint (LBP) on Army buildings. The waste generated by any of these strategies is often hazardous due to the toxicity and leaching characteristics of lead. A straightforward means of selecting the best available strategy and implementing technology for a given application, based on objective criteria and sound engineering judgment, is necessary in order to balance cost, public health, and environmental objectives.

Objective

The objective of this research was to develop a decision tree for selecting the best available strategies and implementing the most appropriate technologies for LBP management on building wall surfaces.

Approach

Two LBP management strategies and their implementing technologies are analyzed here for applicability against a range of selection criteria. The LBP management strategies considered here are (1) abatement and (2) interim controls. Selection criteria include (1) life-cycle cost (LCC), (2) historic preservation, (3) Title X applicability, (4) Army policy, (5) coating condition, (6) substrate condition, (7) substrate material, and (8) exposure environment.

Scope

The results of this study are applicable to interior and exterior wall surfaces of Army buildings coated with LBP. Cleanup, disposal, and post-abatement clearance testing of lead in soil, lead-containing dust on interior building surfaces, and owner/occupant education are outside the scope of this effort. Friction surfaces including doors, windows, stairs, and floors are also not addressed herein.

Mode of Technology Transfer

Technology transfer is being accomplished by: (1) a Technology Transfer Implementation Plan supervised by the U. S. Army Environmental Center (AEC); (2) dissemination of Public Works Technical Bulletin (PWTB) 420-70-2, "Installation Lead Hazard Management"; (3) participation in User Groups and Committees such as the Army Lead and Asbestos Hazard Management Team, Federal Lead-Based Paint Committee Meetings at EPA or HUD, and ASTM Committee E06.23 on Lead Hazards Associated with Buildings; (4) websites maintained by the Assistant Chief of Staff for Installation Management (ACSIM) [http://www.hqda.army.mil/acsimweb/fd/policy/facengcur.htm], AEC [http://aec. army. mil/usaec/], and the U. S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL) [http:// www.cecer.army.mil].

2 Review of Strategies

Introduction

Each LBP management strategy and implementing technology is defined and discussed in terms of applicability, methods, permanence, cost, invasiveness, and technological risk. The applicability of a technology relates to its suitability for use on various substrates. Permanence reflects the method's durability or service life of the material. Invasiveness reflects the method's pollution potential, impact on occupancy, and level of worker protection required. Technological risk relates to potential for a failure to occur and the degree to which the long-term efficacy of the process or material is known.

Abatement

Overview

Abatement of LBP on buildings is defined as the elimination of the lead paint hazard. Elimination of the lead hazard is affected by removing the LBP from the surface, removing the lead-painted component, or by semi-permanently enclosing the lead-coated surface. The four categories of LBP abatement are (1) paint removal, (2) component replacement, (3) enclosure, and (4) encapsulation.

The abatement strategy permanently eliminates (20 years minimum) the lead paint hazard. Compared to using interim controls, abatement provides a long-term solution to the lead paint hazard. Because abatement is unlikely to fail, very little monitoring or reevaluation of the lead hazard is required.

Paint Removal

This group of implementing technologies is intended to completely and permanently eliminate the lead paint hazard by effectively removing most or all of the lead from a surface. Paint removal is applicable to all substrates in both interior and exterior areas. However, not all paint removal methods can be used on all surfaces because some methods will damage some surface materials. Paint removal is by far the

most invasive of the lead paint management practices, and as such it should only be considered when none of the other methods can be expected to control the lead hazard. The cost of paint removal is typically greater than the cost of either encapsulation or enclosure. The various paint removal technologies are discussed below.

High-Temperature Paint Stripping

Paint removal using high-temperature techniques, including open flame and heated metal plates, are not recommended. These methods may produce significant quantities of lead fume that may condense on and contaminate surrounding surfaces.

Low-Temperature Paint Stripping

Low-temperature paint stripping (less than 1100 °F) using hot air guns and scrapers is recommended. Heat guns are effective on wood surfaces but are generally ineffective on metal, concrete, and brick. Heat guns may damage drywall and plaster and are not recommended for these substrates. Finish sanding using a HEPA* sanding tool may be needed to remove traces of paint and smooth the surface for repainting.

Dry Scraping and Sanding

As a paint removal abatement technology, manual dry scraping and sanding are ineffective. Dry scraping and sanding methods produce lead particulate. As a surface preparation technique for either encapsulation or paint stabilization, limited dry sanding and scraping may be used around interior electrical fixtures where wet techniques may pose an electrical shock hazard.

Wet Scraping and Sanding

As a paint removal abatement technology, manual wet scraping and sanding are ineffective. As a surface preparation technique for either encapsulation or paint stabilization, wet scraping and sanding are appropriate for all types of interior and exterior substrates.

* HEPA: high-efficiency particulate air (filter).

HEPA Sanding

As a paint removal abatement technology, HEPA sanding is ineffective. As a surface preparation technique for use prior to encapsulation or paint stabilization, HEPA sanding is appropriate for all types of interior and exterior substrates. Finish sanding using a HEPA sanding tool may be used to remove traces of paint and smooth the surface for repainting after chemical stripping and low-temperature stripping on interior and exterior wood.

Dry Abrasive Blasting

Open dry abrasive blasting is not recommended for paint removal. This method produces large quantities of lead-containing dust. Dry abrasive blast cleaning with containment may be utilized in certain cases. The substrate must be durable (concrete, brick, or metal), and special ventilation requirements are imposed.

Wet Abrasive Blasting

Wet abrasive blasting is generally preferred to dry abrasive blasting because it produces less dust. The applicability of wet abrasive blasting is limited to paint removal from durable exterior substrates such as concrete, brick, and metal.

HEPA Vacuum Blasting

HEPA vacuum blasting is generally preferred to open dry abrasive blasting because dust is collected at the point of generation. The applicability of HEPA vacuum blasting is limited to paint removal from durable exterior substrates such as concrete, brick, and metal. Wet abrasive blasting will generally be preferred over HEPA vacuum blasting in most cases because of better productivity and because it is easier to gage the rate of paint removal and the degree of substrate erosion.

HEPA Vacuum Needle Gun

HEPA vacuum needle guns are appropriate for removing LBP from durable metallic substrates in exterior applications. In some cases they have been used on exterior masonry to clean small areas.

Solvent-Borne Chemical Stripping

Solvent-borne chemical strippers generally produce less dust than other removal methods. Solvent strippers are recommended for interior and exterior paint re-

moval from all types of substrates. Finish sanding of stripped surfaces with HEPA sanding tools may be required to smooth the surface and remove traces of paint. Solvent strippers should not contain methylene chloride because of its toxicity. Chemical stripping may be performed *in situ*, or movable components may be dismounted from the building and treated offsite.

Caustic Chemical Paint Stripping

Caustic paint strippers are generally more effective at removing thick layers of paint than are solvent strippers. However, they are generally less effective on porous substrates such as stucco, concrete, and plaster. Neutralization of the caustic characterization is sometimes difficult to achieve. This residual alkalinity on stripped wood surfaces is thought to help promote lead leaching from within the substrate material to the surface. Residual alkalinity also may result in premature paint failure of the recoated substrate in a damp environment.

Emerging Technologies for Paint Removal

Novel paint removal methods include offsite microwave paint stripping of building components. This process is commercially available in Sweden and Denmark and has been used to remove LBP from historic wood frame windows. Unlike offsite chemical stripping the microwave process does not affect glued window joints (Tellakula, Stephenson, and Kumar 2003).

Another novel paint removal method that has seen limited use is removal of wood siding for offsite stripping by mechanical planing. The method is well suited to the restoration of historic wood structures. However, as with any process used on historic structures, applicability must be determined on a case-by-case basis.

Comparison of Removal Technologies

Table 1 compares the applicability, relative cost, and invasiveness of the paint removal technologies discussed above.

Table 1. Paint removal technologies.

Method	Applicability	Cost	Invasiveness
High-Temp Paint Stripping	Not recommended	NA	Very high
Low-Temp Paint Stripping	Interior and exterior wood	Low to very high	High
Dry Scraping and Sanding	Limited to surface prep around electrical hazards	NA	High
Wet Scraping and Sanding	Limited to surface preparation in conjunction with paint stabilization and abatement	NA	Moderate
HEPA Sanding	Limited to surface preparation in conjunction with paint stabilization and abatement	NA	Moderate
Dry Abrasive Blasting	NA	NA	Very high
Wet Abrasive Blasting	Limited to durable exterior surfaces including concrete, brick, and metal	Moderate	High
HEPA Vacuum Blasting	Limited to durable exterior surfaces including concrete, brick, and metal	Moderate to high	Moderate
HEPA Vacuum Needle Gun	Limited to exterior metal surfaces	NA	Moderate
Caustic Chemical Stripping	Primarily for thick film removal. Limited effectiveness on porous substrates. May cause damage. May lead to paint failures in moist environments.	Moderate to high	Moderate
Solvent-Borne Chemical Stripping	For use on all interior and exterior substrates.	Moderate to high	Low
Microwave	Limited to offsite stripping of components.	NA	Moderate to high
Planing	Limited to offsite stripping of wood siding.	NA	Moderate to high

Component Replacement

Component replacement is defined as the removal of an LBP-contaminated building component. This implementing technology completely and permanently eliminates the lead paint hazard by removing the lead-coated component from the building. Component replacement is much less invasive than lead paint removal, and as such it should always be considered before paint removal as a method to control the lead hazard. However, component replacement is generally more invasive than encapsulation or enclosure.

Component replacement is primarily applicable to friction and impact surfaces such as trim, doors, and windows, which are outside of the scope of this report. However,

replacement is sometimes appropriate for exterior siding and interior walls. Exterior siding is typically abated by enclosure, but for historically significant buildings, exterior siding may be replaced. If abatement is to be performed as part of a major rehabilitation, then interior lead-coated walls may be demolished. Component replacement is typically the most expensive option.

Enclosure

Enclosure is the installation of rigid, durable barrier materials that are mechanically fastened to the building surface. All edges and seams are sealed to keep lead-containing dust inside of the enclosure. The enclosure acts as a dust-tight barrier. For wide, flat surfaces such as interior walls and exterior siding, enclosure is significantly cheaper than component replacement or paint removal. Enclosure typically costs more than encapsulation for broad wall surfaces. However, the greater the degree of paint deterioration and surface preparation that would be necessary for encapsulation, the more likely it is that enclosure will be cost-competitive with encapsulation. Enclosure may also be more durable than encapsulation. Enclosure is less invasive than other forms of abatement as it produces less dust and generates less waste. Enclosures by definition must be durable for a minimum of 20 years. Because the lead remains on the building, periodic monitoring must be performed to ensure that the enclosure remains dust-tight. The long-term effectiveness of enclosure is still under study. In terms of proven efficacy, enclosure is equivalent to encapsulation but less than either paint removal or component replacement.

Any type of surface material may be enclosed, even those that are deteriorated as long as they are structurally sound. A variety of enclosure materials are used on interior walls, including wood paneling, laminated products, drywall, and fiberboard. Other products that are grouped with enclosure materials, but are glued or cemented rather than being mechanically fastened to the substrate, include plastic and ceramic tile, synthetic brick, and stone veneers. Strictly speaking these other products would be better described as *rigid encapsulants*. Exterior enclosure materials include vinyl siding, preformed and formable aluminum sheet, natural or synthetic brick and stone veneers, and stucco applied over fastened wire mesh.

Vinyl and aluminum siding are the least expensive exterior enclosure materials, and drywall the cheapest interior product.

Encapsulation

HUD (1995)defines encapsulation as a process that makes LBP inaccessible by providing a barrier between the paint and the environment. The barrier is formed using a liquid-applied coating (with or without reinforcement materials) or an adhesively bonded covering material. The primary means of attachment for an encapsulant is bonding of the product to the surface; liquid encapsulants bond through chemical adhesion and cladding-type encapsulants are attached using an applied adhesive material.

Surfaces slated for abatement must first be assessed with respect to the applicability of encapsulants. If the LBP or underlying surface is severely deteriorated, then the use of standard encapsulants requires that the underlying surface be repaired and deteriorated paint removed. Some hybrid encapsulant systems, such as liquids applied over a mechanically fastened fiber mesh reinforcement, can be used without first repairing hairline cracks or small holes. In any case, an encapsulant test patch is necessary to determine whether the old paint can be successfully encapsulated.

Encapsulants can be used to overcoat both interior and exterior LBP. The encapsulation process is applicable to all substrate types including plaster, wallboard, concrete, stucco, wood, and metal.

Encapsulants can be less invasive than other forms of abatement. In some cases, residents may not even need to be relocated during the abatement process. Additionally, encapsulation is typically less expensive than other forms of abatement.

Certified encapsulants are warranted to have a 20-year service life. However, their long-term performance has not yet been proven. It is reasonable to expect that encapsulants will be durable on interior surfaces for 20 years or more as long as degradation from impact, friction, and substrate moisture does not occur. However, exterior applications may not be assumed to be as durable, so periodic monitoring of the integrity of the encapsulant is necessary.

Coatings last longer in exterior environments if the substrate is dimensionally stable. Such is the case with concrete, brick, metal, and stucco building surfaces. Wood, on the other hand, absorbs water and goes through significant dimensional changes. These changes, in conjunction with the degradation of the coating itself, usually cause that coatings on exterior wood to begin flaking and peeling in less than 10 years. It is highly unlikely that either conventional coatings or certified encapsulants as they exist today will significantly extend the maintenance cycle on

exterior wood surfaces much beyond the generally accepted maximum life of 7 to 10 years (Williams 1999).

Interim Controls

The interim control strategy does not permanently eliminate the lead paint hazard. Compared to performing abatement, interim controls do not provide a long-term solution to the lead paint hazard. Because interim controls can fail, monitoring or reevaluation of the lead hazard is required on a periodic basis. Interim control techniques include soil treatments, interior dust removal and control, treatment of impact and friction surfaces, and paint stabilization.

Paint stabilization is defined as the repair of deteriorated paint. Paint stabilization includes repairs to the substrate, surface preparation, and recoating of the surface. As with encapsulation, the underlying causes of paint deterioration, such as moisture migration, must also be corrected. Surface preparation includes cleaning, deglossing, and removal of deteriorated paint. Repainting includes the application of a primer and one or more topcoats. When the stabilized paint begins to deteriorate again, the maintenance procedure is repeated. Paint stabilization can control lead hazards provided all of the paint layers remain intact.

The primary limitation of paint stabilization is the frequency of repainting necessary to keep the lead-coated surface in good condition. Exterior applications on wood surfaces may require maintenance every 3 to 7 years to maintain the paint in good condition (Williams 1999). However, this repaint cycle is consistent with current Army installation practices where exteriors are repainted on a 5-year cycle. It should be noted that certain maintenance painting practices can extend the repaint cycle to up to 10 years (Williams 1999) on wood substrates. Paint systems on concrete and stucco may last 20 or more years (Bartlett 2001).

Other limitations of the paint stabilization process are similar to those encountered with encapsulants. Proper surface preparation is a critical component in paint stabilization. All deteriorated paint must be removed to ensure long-term performance. Surface preparation is the most important step in any coating operation. Duration of performance correlates strongly with the quality of surface preparation. Also, periodic monitoring of the integrity of the stabilized paint is necessary because lead remains on the structure and could become available to the environment if any portion of the containment coating fails.

As with encapsulants, friction and impact surfaces such as doors, stairs, floors, and windows must be treated differently — not merely cleaned and repainted with conventional coatings. Other surfaces that should generally be dealt with by other means include lead-coated hot water radiators and old calcimine coatings.

Current interior painting practice at Army installations is to recoat after 3 years. In real-world operations, however, repainting may be performed more often, with each change of tenant. HUD guidelines indicate that interior paint jobs on wood and plaster surfaces can last 5 to 10 years with only minor fading. By that standard, Army practices are more than sufficient to ensure that interior lead-coated surfaces remain in good condition where paint stabilization is practiced.

Based on available data, interim controls are qualitatively equivalent to abatement using encapsulant coatings. Both methods reduce lead dust levels and resident children blood-lead levels.

Except for the restrictions already discussed, there is no limitation on the applicability of interim controls based on substrate type, interior or exterior exposure, or type of architectural component. However, it should be recognized that the required frequency of maintenance repainting will be specific to the coating end-use.

The cost of paint stabilization is highly dependent on the condition of the substrate and existing paint. Where substrate and paint deterioration are severe, the cost of paint stabilization will be high. In some cases the cost may exceed the cost of abatement, especially when life-cycle costs are evaluated. However, the same cost considerations hold true for abatement by encapsulation. Severely degraded surfaces may also increase the cost of other forms of abatement.

3 Criteria for Selecting an LBP Hazard Management Strategy

Introduction

Strategy selection criteria can be classified as either regulatory/policy-driven or technology-driven. Regulatory/policy type selection criteria carry greater weight and have greater impact than the technology considerations on the selection of a strategy.

Regulatory/policy-driven strategy selection criteria include historic preservation, building occupancy, and Army policy. Technology-driven selection criteria are substrate condition, paint condition, exposure, and substrate material. This chapter discusses the major strategy selection criteria and generally indicates how each fits into the context of a decision tree.

Criterion 1: Historic Preservation

Historic preservation is the most comprehensive of all of the selection criteria. Before conducting lead hazard control activities on buildings listed or eligible for listing in the National Register of Historic Places, the State Historic Preservation Office (SHPO) must be consulted. The lead hazard control strategy should be negotiated with the SHPO. Where a large number of historic buildings are affected at a given installation there may be previously regulated programmatic agreement between the installation and the SHPO that clearly defines which kinds of lead hazard management activities are acceptable.

Several historic preservation principles will affect strategy selection. The removal of significant historic materials should be avoided, as should techniques that damage significant historic materials. Also, whenever possible and financially feasible, the covering historic siding should be avoided. The goal is to preserve as much historic fabric and detailing as possible. It should be noted that the decision tree process is not a substitute for historic preservation guidance and processses. The deci-

sion tree attempts to identify which types of procedures may be acceptable to the SHPO.

The preferred lead hazard control technique for historic buildings is interim control using paint stabilization. The next-least invasive strategy is abatement by paint removal. Recommended methods of paint removal include low-temperature paint stripping (less than 450 °F) and scraping, solvent-based paint strippers, and offsite paint stripping with heat or chemicals. For durable exterior substrates such as metal, brick, and concrete, wet abrasive blasting with soft media such as sodium bicarbonate or sponge media may be acceptable if other techniques are not feasible and the substrate is not damaged by the process. High-temperature paint stripping, wet or dry abrasive blasting with any hard medium, aggressive power tools, caustic chemical strippers, and hot-tank chemical stripping are not recommended.

In some cases the substrate may be so degraded that surface preparation for paint stabilization or paint removal will further damage the substrate. In such cases where paint stabilization and paint removal are not feasible, component replacement may be considered. However, removed components should always be replaced or replicated in accordance with the applicable historic preservation or rehabilitation authority.

Liquid non-reinforced encapsulants are thick film coatings that can hide significant surface details, and therefore these are not appropriate for use over decorative detailed elements. Encapsulants also should not be used on wood substrates in damp exterior environments because they may trap moisture in the wood, causing deterioration of the wood over long periods of time.

Reinforced encapsulants may be appropriate for degraded interior plaster walls within simple interiors.

Enclosure of exterior siding is not recommended. Enclosure of interior elements may be acceptable as a temporary treatment provided the enclosed surface is not damaged or altered.

Historic preservation requirements must be carefully balanced with other competing interests, especially childhood health and economics.

Criterion 2: Child Occupancy

This criterion encompasses lead hazard control both for child-occupied buildings (e.g., family housing, childcare facilities, and schools) and non-child-occupied buildings (e.g., offices, equipment rooms, utility sheds, storage facilities, and shops). Lead hazard control in child-occupied facilities is regulated under Title X (Public Law 102-550). Lead hazard control in non-child-occupied facilities is not regulated. Strategies differ for managing lead hazards in these two distinct building types. There is no mandate to affect lead hazard control in non-child occupied buildings. However, from a pragmatic standpoint, it is recognized that these buildings must be maintained, so it is important to perform maintenance in a lead-safe manner that protects the environment and building occupants. It is also important that resources are used in a cost-effective manner.

Paint stabilization is always the best approach to maintaining lead-coated buildings that are not occupied or used by children. In some cases where the substrate and or existing painting are severely degraded it may be more cost-effective to enclose the surface. The presence of lead dictates lead-safe work practices and OSHA*-required worker training. These requirements as well as the high cost of removing large amounts of deteriorated coating usually mean that enclosure is less expensive.

Criterion 3: Army Policy

Army Regulation (AR) 420-70 states that "lead-contaminated paint will be abated only when interim controls are ineffective or when economically justified for major repair or whole neighborhood revitalization projects." And further, it states that "such paint will not be removed solely for the purpose of abatement." Army policy has clearly established paint stabilization as the preferred lead hazard control strategy. Abatement should be performed only when paint stabilization cannot control the lead hazard. Paint stabilization is effective at controlling the lead hazard except on friction and impact surfaces, which are outside of the scope of this project. So paint stabilization will always be performed except where abatement is more cost-effective. Abatement may in fact be more cost-effective where the extent of substrate damage and/or paint deterioration is severe. Army policy also indicates that abatement may be cost-effective in the context of whole neighborhood revitali-

* OSHA: Occupational Safety and Health Administration.

zation or major repairs. In some cases an economic assessment may be appropriate to clarify the issue.

Criterion 4: Substrate Condition

Substrate degradation must be repaired before repainting. If the extent of substrate degradation is so great that paint stabilization is more expensive than at least one form of abatement, then for the purposes of the decision tree, the surface is considered to be in poor condition.

Criterion 5: Existing Paint Condition

Deteriorated paint must be removed before repainting. If the extent of paint deterioration is so great that paint stabilization is more expensive than at least one form of abatement, then for the purposes of the decision tree the existing paint condition is considered to be poor.

Criterion 6: Exposure

For the purposes of the decision tree, a distinction is drawn between lead hazard control on interior and exterior surfaces. Interior surfaces are more critical than exteriors in terms of potential exposure of inhabitants to the toxic lead characteristic. Exterior surfaces are more critical than interiors in terms of the potential release of lead contamination into soil or water due to weathering and harsh environmental exposure.

Criterion 7: Substrate Material

The durability of substrate materials is a significant consideration within the decision tree. Plaster, drywall (sheetrock), and stucco are grouped together because similar types of paint removal techniques are effective on each. Harder surfaces such as concrete, stone, brick, and metal are also grouped together for the same reason. Wood encompasses some additional considerations and is addressed separately.

4 Explanation of the Decision Tree

Introduction

A decision tree is a kind of roadmap to help guide a decision-making process through specific sets of conditions to arrive at an appropriate, defensible decision. Used frequently in engineering environments, a decision tree can help the user select the most suitable course of action from among several competing alternatives. The decision tree method employed here is known as *binary recursive partitioning.* The process is binary because each parent node is split into two child nodes. The process is recursive because each successive child node is treated as a parent node until a node terminates in a solution. The methodology used here asks questions that call for an answer of yes or no. The terminating nodes provide recommended strategies.

Note: The technologies considered in this decision tree are proven, established technologies that are available through multiple vendors and that are documented with cost and performance data collected over many years in varying applications. Emerging technologies are *not* considered in the current decision tree. However, as these technologies mature and become more cost-effective, they should be introduced as viable alternatives. For example, the microwave paint stripping process is currently used in Sweden and Denmark to remove paint from windows (p 6).

Description of the Decision Tree for Lead Hazard Management

Incorporation of Hazard Management Selection Criteria Into Decision Tree Queries

This decision tree uses a maximum of eight queries to determine a solution for a given set of circumstances. Each question and answer encompasses significant technical meaning and requires the user to be knowledgeable about facility condition and occupancy. The user must have conducted a preliminary investigation of the substrate and paint condition. The quality of the decision tree output is driven by the quality of the information gathered before the query process begins.

Table 2 shows the eight queries that form the basis for the decision tree. Readers may note that there is not a one-to-one correspondence between lead the hazard management selection criteria (as explained in Chapter 3) and the decision tree queries. There are two reasons for this:

2. Army policy is in effect a boundary condition that pertains to all decisions, so there is no need for the decision tree user to be queried about whether AR 420-70 applies — the answer is always *yes*, even when other mandates also apply.
3. Up to three queries must be used to ensure correct identification of the substrate materials based on durability, surface hardness, water absorbency, etc.

Table 2. Lead hazard management criteria in question form.

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Q2. Is the building a child-occupied facility addressed by Title X?
Q3. Is the substrate in poor condition?
Q4. Is the existing paint in poor condition?
Q5. Is the work interior?
Q6. Is the substrate wood?
Q7. Is the substrate metal, concrete, stone, or brick?
Q8. Is the substrate plaster, wallboard, or stucco?

Output Decisions

The query process provides just four possible lead hazard management strategies for buildings where historic preservation is not an issue, as described below.

Enclosure. The enclosure strategy is indicated for interior and exterior wood where either the substrate or existing paint is in poor condition as defined herein. Enclosure is also selected for non-Title X work on all substrates where either the substrate or existing paint is in poor condition as defined herein.

Enclosure or Reinforced Encapsulants. Abatement by enclosure or reinforced encapsulants is indicated for Title X interior surfaces other than wood where either the substrate or the existing paint is in poor condition as defined herein. This option is also selected for Title X exteriors where the substrate material is stucco and either the paint or the substrate is in poor condition.

Enclosure, Reinforced Encapsulants, or Wet Abrasive Blast. Abatement by enclosure, reinforced encapsulants, or wet abrasive blasting is indicated for Title X exte-

rior hard surfaces including concrete, stone, brick, and metal where either the substrate or the paint is in poor condition as defined herein.

Paint Stabilization. Interim control by means of paint stabilization is indicated for all Title X and non-child-occupied buildings on all substrates where the paint and substrate condition are not in poor condition as defined herein.

For buildings where historic preservation is an issue, there are six outputs that present maintenance options that should be proposed to the SHPO or included in any applicable programmatic agreement.

Low-Temperature Paint Stripping or Component Replacement. Abatement by low-temperature paint stripping or component replacement is proposed for interior and exterior wood where either the substrate or paint condition is poor as defined herein.

Solvent-Based Paint Stripping. Abatement using solvent-borne paint stripper is proposed for hard interior surfaces including metal, concrete, stone, and brick where either the substrate or the existing paint is in poor condition as defined herein. This option is also selected for exteriors where the substrate material is stucco and either the paint or the substrate is in poor condition.

Reinforced Encapsulant. Abatement using reinforced encapsulants is proposed for soft interior surfaces including plaster and drywall where either the substrate or the paint condition is poor as defined herein.

Solvent-Based Paint Stripping or Wet Abrasive Blasting. Abatement using solvent-borne paint stripper or wet abrasive blast is proposed for hard exterior surfaces including metal, concrete, stone, and brick where either the substrate or paint condition is poor as defined herein.

Low-Temperature Paint Stripping. Abatement by low-temperature paint stripping is proposed for interior and exterior wood surfaces where the paint is in poor condition as defined herein.

Paint Stabilization. Interim control by means of paint stabilization is proposed for all interior and exterior substrates where the paint and substrate condition are not in poor condition as defined herein.

Graphical Presentation of the Decision Tree

Because of the complexity of the tree and its large size, individual branches of the tree are shown separately in the appendix to this report, from the first parent node to the final output decision. A total of 29 branches are depicted. Table 3 summarizes the branches of the decision tree.

Table 3. Summary presentation of decision tree branches.

Branch No. and Output	Combinations of Responses to Numbered Queries							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
B1. propose LTPS or CR	Y	--	Y	Y	Y	Y	--	--
B2. propose SBPS	Y	--	Y	Y	Y	N	Y	--
B3. propose RE	Y	--	Y	Y	Y	N	N	Y
B4. propose LTPS or CR	Y	--	Y	Y	N	Y	--	--
B5. propose SBPS or WAB	Y	--	Y	Y	N	N	Y	--
B6. propose SBPS	Y	--	Y	Y	N	N	N	Y
B7. propose LTPS	Y	--	N	Y	Y	Y	--	--
B8. propose SBPS	Y	--	N	Y	Y	N	Y	--
B9. propose RE	Y	--	N	Y	Y	N	N	Y
B10. propose LTPS	Y	--	N	Y	N	Y	--	--
B11. propose SBPS or WAB	Y	--	N	Y	N	N	Y	--
B12. propose SBPS	Y	--	N	Y	N	N	N	Y
B13. propose PS	Y	--	N	N	--	--	--	--
B14. Encl	N	Y	Y	Y	Y	Y	--	--
B15. Encl or RE	N	Y	Y	Y	Y	N	Y	--
B16. Encl or RE	N	Y	Y	Y	Y	N	N	Y
B17. Encl	N	Y	Y	Y	N	Y	--	--
B18. Encl or RE or WAB	N	Y	Y	Y	N	N	Y	--
B19. Encl or RE	N	Y	Y	Y	N	N	N	Y
B20. Encl	N	Y	N	Y	Y	Y	--	--
B21. Encl or RE	N	Y	N	Y	Y	N	Y	--
B22. Encl or RE	N	Y	N	Y	Y	N	N	Y
B23. Encl	N	Y	N	Y	N	Y	--	--
B24. Encl or RE or WAB	N	Y	N	Y	N	N	Y	--
B25. Encl or RE	N	Y	N	Y	N	N	N	Y
B26. PS	N	Y	N	N	--	--	--	--
B27. Encl	N	N	Y	Y	--	--	--	--

Branch No. and Output	Combinations of Responses to Numbered Queries							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
B28. Encl	N	N	N	Y	--	--	--	--
B29. PS	N	N	N	N	--	--	--	--

Notes for table: Rows B1 – B13 (shaded) indicate outputs where historic preservation is an issue, and "propose" means "propose to the applicable State Historic Preservation Office." Abbreviations are as follows: "B" is branch; "LTPS" is low-temperature paint stripping; "SBPS" is solvent-based paint stripping; "WAB" is wet abrasive blasting; "RE" is reinforced encapsulant; "CR" is component replacement; "Encl" is enclosure; "PS" is paint stabilization.

Limitations of the Decision Tree

The lead hazard management decision tree is not intended to serve as a substitute for the economic analysis process. Some outputs provide more than one approach to lead hazard control. The specifier may elect to further reduce the number of options by comparing additional cost data. The specifier may also choose one strategy over another based on aesthetic considerations. For example, exterior stucco in poor condition can be effectively abated using either reinforced encapsulants or enclosures. However, a vinyl siding enclosure will change the appearance of the building to a much greater extent than would a reinforced encapsulant over the same surface.

The decision tree is also not a substitute for complying with historic preservation statutes. Before conducting lead hazard control activities on buildings listed in or eligible for listing in the National Register of Historic Places, the State Historic Preservation Office (SHPO) must be consulted. The decision tree produces outputs that are sensitive to the principles of historic preservation, but the outputs provide only a starting point for proposing lead hazard control methods to the SHPO.

5 Summary

A lead hazard control decision tree was developed for buildings. The tree encompasses a consideration of lead hazard management strategies, strategy selection criteria, and building-specific information to help the user arrive at an appropriate and defensible method for managing or eliminating the hazards associated with aged LBP on building interiors and exteriors.

The lead management strategies incorporated into the decision tree are:

- abatement
- component replacement
- enclosure
- encapsulation
- interim controls.

The criteria influencing strategy selection are:

- historic preservation
- child occupancy
- Army policy
- substrate condition
- existing paint condition
- exposure
- substrate material.

The decision tree yields multiple outputs or decisions on 29 branches using only eight queries. The tree is presented graphically as branches showing the logic flow for each decision.

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ASTM E 1797, *Standard Specification for Reinforced Liquid Coating Encapsulation Products for Leaded Paint in Buildings.*

ASTM E 2052, *Standard Guide for Identification and Management of Lead Hazards in Facilities.*

ASTM E 2115, *Standard Guide for Lead-Hazard Assessments of Residential Housing and Other Properties Frequented by Children.*

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Appendix: Decision Tree Branches

Branch 1

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = Yes
Decision = Propose low-temperature paint stripping or component replacement.

Branch 2

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Propose solvent-borne paint stripping.

Branch 3

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Propose reinforced encapsulant.

Branch 4

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = Yes
Decision = Propose low-temperature paint stripping or component replacement.

Branch 5

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Propose solvent-borne paint stripping or wet abrasive blasting.

Branch 6

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Propose solvent-borne paint stripping.

Branch 7

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = Yes
Decision = Propose low-temperature paint stripping.

Branch 8

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Propose solvent-borne paint stripping.

Branch 9

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value =Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Propose reinforced encapsulants.

Branch 10

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = Yes
Decision = Propose low-temperature paint stripping.

Branch 11

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Propose low-temperature paint stripping.

Branch 12

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Propose solvent-borne paint stripping.

Branch 13

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = No
Decision = Propose paint stabilization.

Branch 14

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = Yes
Decision = Enclosure is recommended.

Branch 15

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 16

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 17

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = Yes
Decision = Enclosure is recommended.

Branch 18

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Enclosure, reinforced encapsulant, or wet abrasive blasting are recommended.

Branch 19

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 20

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = Yes
Decision = Enclosure is recommended.

Branch 21

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 22

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = Yes
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 23

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = Yes
Decision = Enclosure is recommended.

Branch 24

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = Yes
Decision = Enclosure, reinforced encapsulant, or wet abrasive blasting are recommended.

Branch 25

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Q5. Is the work interior?
Value = No
Q6. Is the substrate wood?
Value = No
Q7. Is the substrate metal, concrete, stone, or brick?
Value = No
Q8. Is the substrate plaster, wallboard, or stucco?
Value = Yes
Decision = Enclosure or reinforced encapsulant are recommended.

Branch 26

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = Yes
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = No
Decision = Paint stabilization is recommended.

Branch 27

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = No
Q3. Is the substrate in poor condition?
Value = Yes
Q4. Is the existing paint in poor condition?
Value = Yes
Decision = Enclosure is recommended.

Branch 28

Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = No
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = Yes
Decision = Enclosure is recommended.

Branch 29
Q1. Is the building listed on or eligible for the National Register of Historic Places?
Value = No
Q2. Is the building a child-occupied facility addressed by Title X?
Value = No
Q3. Is the substrate in poor condition?
Value = No
Q4. Is the existing paint in poor condition?
Value = No
Decision = Paint stabilization is recommended.

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14. ABSTRACT

A lead hazard control decision tree was developed for buildings. The tree yields multiple outputs or decisions on 29 branches using only eight queries. This decision tree addresses both lead hazard control for child occupied buildings including family housing, childcare facilities, and schools and non-child occupied buildings such as offices, equipment, utility, storage, shop, and other non-child occupied buildings.

The decision tree employs eight queries to determine a solution for a given set of circumstances. However, each question and answer is laden with significant meaning and requires the user have knowledge from the preliminary investigation of the substrate and paint condition. The criteria presented in query format are based on strategy selection criteria combining regulatory/policy driven strategy selection criteria include: historic preservation, building occupancy, and Army policy. Technology driven selection criteria are substrate condition, paint condition, exposure, and substrate material.

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Lead-based paint, paint, hazardous waste, operation and maintenanace

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